Hanke and St. John

Tests of an Otto Suction Gas Producer And Gas Engine

Mechanical Engineering

B. S.

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TESTS OF AN OTTO SUCTION GAS PRODUCER AND GAS ENGINE

BY

Frederick Edward Hanke
Alfred Harvey St. John

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

IN THE
COLLEGE OF ENGINEERING
OF THE
UNIVERSITY OF ILLINOIS
PRESENTED JUNE, 1907.

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June 1, 1907

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FREDERICK EDWARD HANKE and ALFRED HARVEY ST. JOHN

ENTITLED TESTS OF AN OTTO SUCTION GAS PRODUCER AND GAS ENGINE

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering

102759

-:C O N T E N T S:-

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COMMERCIAL TEST OF OTTO SUCTION GAS PRODUCER & ENGINE.

I Preliminary Remarks.

These tests were made in the Mechanical Engineering Laboratory of the University of Illinois for the purpose of determining the cost of power production at varying loads with the present installation.

II Description of Plant.

This plant consists of an Otto gas producer rated at 60 horse power, and an Otto engine rated at 23 horse power. General view of the plant is shown on page 19.

The producer operates on hard coal and is of the suction type, i.e. the draft for the fire is produced by the suction stroke of the engine. The producer consists of four principal parts: the generator, economizer, scrubber, and receiver. In this type, the economizer and generator are integral, the former being in the shape of a water jacket surrounding the incandescent fuel bed. The scrubber, shown to the right of the generator, is cylindrical in form and filled with coke. The receiver is a small cylindrical drum situated beneath the floor between the scrubber and engine. The principal dimensions of the producer are as follows:-

Grate Area ----------	2.04 Sq. Ft.
Volume of Magazine---------	16.3 Cu. Ft.
Volume of Economizer-------	1.2 " "
Diamater of Scrubber-------	2'- 9"
Height of Scrubber---------	12'- 7"

Diameter of Receiver---------- 1' - 9"

Length of Receiver---------- 3' - 6"

Diam. of Gas Pipe to Engine---- 5"

The 23 horse power engine is single acting four cycle and of Otto make,and is shown on page 18 . The engine has three valves air intake, gas intake, and exhaust. These are poppet,and are opened by levers operated by cams on the cam shaft. An additional cam on this shaft allows for release of compression when starting. The governor is of the fly ball type geared to the cam shaft, and controlls for 22o R.P.M. by the hit and miss method. The principal dimensions of th engine are as follows:-

Stroke----------	19	in.
Cyl. Diameter----------	10	"
Diam. Fly Wheel --------	8o	"
Length of Conn. Rod-----	45	"

III Operation of Plant.

Green coal is charged into the producer at B Fig.4 p.21 and is brought into a state of incandescence upon the grate G for a depth of about two feet. Fire brick FF protect the surrounding cast iron from the intense heat. The suction stroke of the engine draws air into the producer at A . Surrounding the incandescent coal,is the boiler W in which the water is partly vaporized. The air,passing from A over the surface of the water, takes up moisture and is further sucked through pipe K, drawn under the grate,and thence through the incandescent coal. Here chemical reaction takes place between the air,water vapor, and the carbon, aided by the heat of combustion,resulting in the formation of gas. The gas passes through the pipe PP and the water seal T into the scrubber C. The object of the scrubber is to wash or rid the gas of tar and other impurities by means of the spray of water entering at the top and playing over the coke contained. Because of the porous nature of the coke,the water and gas particles are brought into more thorough contact and better purification results. Before entering the engine , the gas passes through the receiver R , the purpose of which is to equalize the gas pressure. In starting, owing to the absence of engine suction, the producer is given a forced draft by means of fan blower O, operated by opening valve D for admission and closing valve E to prevent exit of draft through A . Usually from one half to one hour is required to generate gas of the requisite quality for running, and until such is obtained, the producer is disconnected from the scrubber by closing valve J

and thrown into communication with the atmosphere by opening valve F. With the valve J closed, the water fills the seal, and thus prevents the gas from entering the scrubber.

IV Theory.

It is the purpose of the gas producer to produce incomplete combustion, thereby forming gases combustible in the engine. These gases contain a large amount of carbon monoxide CO and H, small portions of hydrocarbons $C_X H_V$, possibly tar and smoke. The process is essentially as follows: as the coal becomes heated in the combustion chamber, the light volatile gases are driven off. In being further heated the coal comes to a state of incandescence and is completely burned forming carbonic acid CO_2 The CO_2 passes through the incandescent bed and becomes highly heated in contact with the carbon of the fuel. Here it combines chemically with the carbon and is converted into carbon monoxide CO, as indicated by the chemical equation $CO_2 + C + \text{Heat} = 2CO$ With dry air and no impurities in the fuel the gas contains by volume approximately 34.7 % of CO and 65.3 % of Nitrogen N. Where there is considerable moisture present the gas contains a large amount of hydrogen as shown by the chemical equation $H_2O + C + \text{Heat} = 2H + CO$ Apparently this seems to indicate economy, but closer investigation shows that such is not the case The introduction of moisture to the glowing fuel, above a certain amount, causes a reduction in the temperature and heat necessary for the carbonization of the CO_2.

The advantage of the producer process is that the combustion, partial only in the producer, is completed in the engine under conditions favoring a fuller realization of the heat value otherwise impossible. Although there is a loss of energy usually not more than 15 to 20% of the calorific value of coal, yet experience has demonstrated that in the majority of cases producer gas accomplishes the same result as direct firing but with less coal. It is the correctness of this statement that the tests made attempt to confirm.

V Apparatus

The dynamometer used for measuring the brake horse power is the ordinary prony brake, with 62 3/4" Brake Arm. This is shown in photograph no.3 of p.2o.The pulley was kept cool by a strdam of water playing upon the inside.

Two Buffalo scales were used, one for supporting the brake arm and one for weighing coal.

The explosion counter consists of ordinary counting disks operated by an electromagnet. One end of the circuit was fastened to an insulated brass arm bolted to the engine directly above the lever operating the gas intake valve,and the other terminal to the lever. When intake occured,the lever came in contact with the brass strip and closed the circuit. Since the engine is hit and miss governedthe miss explosion is caused by failure of the gas intake valve to open. The lever arm operating this valve therefore does not oscillate and no contact of circuit terminals is made.

Two gas engine indicators were used with 12o# and 16o# spring s. The indicator was mounted at the head end of the cylinder at the center of the top.

Reduction of piston travel was obtained by fastening the indicator cord near the upper end of an oscillating arm linked to the piston and pinned to a supporting rod.

A speed counter and watch were used for obtaining the R.P.M.

Ordinary service meters were used for measuring the water supply to the jacket and to the producer,and were connected directly in the pipe line.

Fahrenheit thermometers of suitable ranges were used to obtain the following temperatures:

Gas at Producer, taken in horizontal pipe P Fig.4 immediately outside of producer.

Water entering the scrubber, and generator taken at the entrance to engine jacket.

Water leaving jacket, at the center of the top of the cylinder.

Water leaving the scrubber, at the discharge basin N Fig. 4

Gas entering the engine, at entrance pipe immediately joining the intake valve

Gas at the exhaust, beyond the head of the exhaust drum.

All temperatures were obtained by inserting thermometers in oil sockets.

VI Manner of Conducting Test.

In order to obtain a commercial test, where cost of power is the greatest importance, it was thought advisable to run a series of tests at a quarter, half, three quarters, full, and overload for eight hour periods each. Full and overload tests were not obtainable sin ce the engine would not run over three quarter load. The maximum eight hour load obtainable was five eights. No difficulty was encountered although frequent pokings of the fire were necessary. A three quarter load test was run but after five and a half hours of running under fluctuating conditions the engine slowed down and wide variations in R.P.M., I.H.P., and B.H.P. made this test unreliable and results were not plotted in the final curve.

A short preliminary test was run before starting the tests proper. In this test it was purposed to get everything in good running order. A few readings of temperatures, R, P.M., etc. were taken in order to obtain an idea of what might be expected. During this test, indicator cards were taken to secure the proper spark adjustment and air supply. It was found that too early or late ignition gave a flat card with a low mean effective pressure. The same effect was produced by an insufficient or excessive air supply. The cards mounted on the following pages are samples taken from each test and show the correct adjustment.

The tests proper were begun with a clean grate and ash pit, a full coal magazine, and engine and producer operating under constant conditions. The tests were closed withthe magazine full, and the ash pit and grate clean. In starting the engine, gasoline was

used to obtain full speed after which gas was admitted.

Readings were taken every fifteen minutes, and were as follows.

Temperatures of Gas at Producer

" " " " Engine

" " " " Exhaust

" " Water entering Producer

" " " leaving "

" " " entering Jacket

" " " leaving "

R.P.M.

Pressure at End of Brake Arm.

Explosion Counter

Cubic Feet Water to Jacket and Producer.

The brake load on the scales was kept constant by adjusting the friction on the brake pulley. No continuous measurements of coal consumption were made. At the close of the test the amount of coal necessary to fill the producer magazine was weighed. In order to keep running conditions as nearly constant as possible, at no time during the test was the producer opened. Frequent poking of the grate from above and below was necessary to prevent the formation of clinker. The coal used was pea size of anthracite. Half a dozen samples were taken from each test. At the end of the tests all samples were thoroughly mixed and five pounds of this mixture was taken for chemical analysis. Owing to the overflow from the producer boiler leading below the grate, the ashes were dampened considerably, and because of this it was necessary to dry them for twenty four hours before weighing them.

VII Calibrations

In order to secure accurate results, careful calibrations were made of the following apparatus: thermometers,scales,water meters,and indicator springs. Calibrations of thermometers for working ranges were made by comparison with a standard thermometer inserted in the same bath. Scales were tested by th ¢use of standard weights. By means of the oil gage tester, known pressures were applied to the indicator springs by increments of twenty pounds and the corresponding pencil displacements recorded on the card. Water meters were calibrated at approximately the same rate of flow used throughout the tests by weighing the water run through them.

VIII Calculations.

Corrections for temperature readings were made by means of calibration curves. Since the scales were found to be accurate no corrections were applied. The ratio of the actual to the observed discharge through the meters gave the correction factor which was used in correcting the water measurements. From the calibration cards of the indicators, the ration of the average actual pressures to the average observed pressures gave the correction factor.

In determining the pressure on the scales at the end of the brake arm, use was made of the formula:

$$B.H.P. = \frac{(2)\,(3.1416)\,R\,N\,P}{33000}$$

Where R = Length of brake arm in feet

N = R.P.M.

P = Pounds registered on the scales

Substituting in this equation 220 for N , 62 3/4 " ÷ by 12 for R, and 1 for B.H.P. we obtain the pressure of 4.56# necessary for one horsepower. Since the normal load of the engine is 23 H.P. the pressure on the arm for any load,as one quarter, equals

$$\frac{23}{4}\ 4.56 = 26.2\#$$

The B.H.P. for each set of readings was calculated using the recorded R.P.M.

The sample calculations below are made for the first set of readings of the 1/4 load test.

$$B.H.P. = \frac{(2)(3.1416)\,R\,N\,P}{33000} = \frac{(2)(3.1416)(62.75)\,222(26.2)}{12 \quad (33000)}$$

$$= \quad 5.78 \text{ Horse power.}$$

Calculation of indicated horse power is as follows:

$$I.H.P. = \frac{P\,L\,A\,N}{33000}$$

Where P = Mean effective pressure

L = Length of Stroke in Feet.

A.= Area of Piston in Square inches.

N = Number of Explosions per minute.

N was obtained by subtracting the successive fifteen minute readings of the explosion counter and dividing by fifteen.

$$I.H.P. = \frac{P\,L\,A\,N}{33000} = \frac{(54)\,\frac{19}{12}\,\frac{(5)(10)^2}{4}\,\frac{873}{15}}{33000} = 9.3$$

Mechanical and Thermal efficiencies are calculated as follows:-

$$\text{Mech. Eff.} = \frac{B.H.P.}{I.H.P.} = \frac{5.73}{9.30} = 61.9\,\%$$

$$\text{Therm.Eff.} = \frac{\text{B.T.U. Output}}{\text{B.T.U. Input}} = \frac{(5.75)\,33000\,(495)}{(151)(778)\,13207} = 6.05\,\%$$

$$\#\text{ Coal per B.H.P.H.} = \frac{\text{Total Coal used}}{B.H.P.H.} = \frac{(151)}{(5.75)\,8.25} = 3.02$$

IX Discussions, Curves, & Conclusions.

A noticeable feature of the high load tests was the inability of the engine to carry the load. The greatest care in the adjustment of the spark and air supply ,as well as the careful attention to the fire, failed to make the engine carry more than about 16 horse power. We believe, that the combination of a 60 horse power producer with a 23 horse power engine was to a large extent responsible for this state of affairs. In order to obtain gas of a sufficient calorific value to maintain normal load in the engine a comparitively high furnace temperature (about 1000 ^{o} F.) is absolutely necessary. Since the producer is of the suction type, it depends entirely upon the suction of the engine for its draft. With such a large producer , it is natural to suppose that the suction of a 60 horse power engine or equivalent is intended to give the draft to produce the proper furnace temperatures. R.D.Wood & Co. in their catalog on gas producers state that a frequent temperature of the gas leaving the producer is about 1100 ^{o} F. Comparing this figure with the highest temperature obtained,it is at once evident that the proper furnace heat is lacking,and the necessary reactions do not take place freely enough. Furthermore, because of the low temperature, the evaporation of the water in the boiler is insufficient and consequently the hydrogen gas constituent which is due to the water vapor is lacking. Another function of the water vapor is to prevent the formation of clinker, the presence of which obstructs the free flow of air through the incandescent fuel bed. The increase of clinker formation with the load is very noticeable and at times

it became impossible to run the splice bar to the grate. At one quarter and one half load tests, the operation of the plant was entirely satisfactory, there being no trace of clinker at one quarter load and only a small amount at one half load. This is easily explained from the fact that at low loads the fusing point of the ash was not reached. A less important cause for the inability of the engine to carry full load was the dust and dirt in the coal used. To get the best results from this type of producer it is essential to have a large surface of incandescent fuel exposed to the rising CO_2 gases, and this is facilitated by decreasing the size of the coal. There is, however, a point where the passage of air is sensibly obstructed by decreasing the size of the coal. This is what occurs when large quantities of dust and dirt are present, and in this way the already too small an engine suction was still further decreased causing a possible rarified charge in the engine cylinder, and resulting in a corresponding lowered M.E.P.

The final results of tests are shown by curves No. 1, 2, & 3. The points on these curves were plotted from average values of each test.

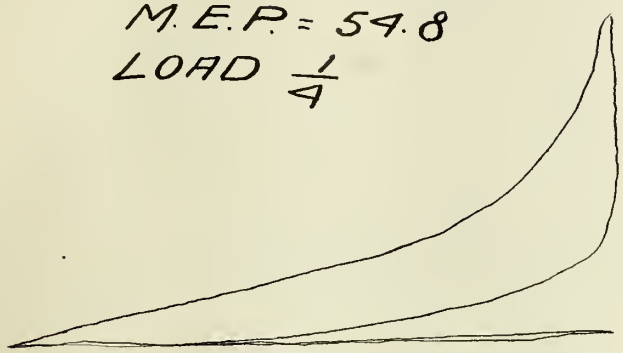
Curve No. 1 shows the relation between the mechanical efficiency and the load. With the load the mechanical efficiency of the engine increases. This is what might be expected as a large part of the friction of the engine is constant and only a small part varies with the load, so that at high horse power output the percent of frictional loss will be smaller and the mechanical efficiency greater.

Curve No. 2 shows the relation between the pounds of coal per B.H.P.H. and load at the brake. This curve shows the most economical performance to be at five eighths load and the poorest economy to be at one quarter load. It is readily seen that the economy increases with the load. Owing to the inability to run the engine at larger loads, the most economical point of performance was unable to be found. From what it was possible to do with the engine,however,the conclusion is evident that a gas engine of this character has a point of particular economy and the performance at other loads is much less economical. For a small unit the coal consumption of 1.85 # per B.H.P.H. is good and worthy of attention,as it shows the superior economy of this kind of plant over the small steam install ation . Steam engines of 12 to 60 I.H.P. have coal consumptions of 8 to 36 # coal per B.H.P.H. The conditions of installation,kind of boiler and engine will,of course, have much to do with the coal rate, but seldom will a plant do better than 10# coal per B.H.P.H.

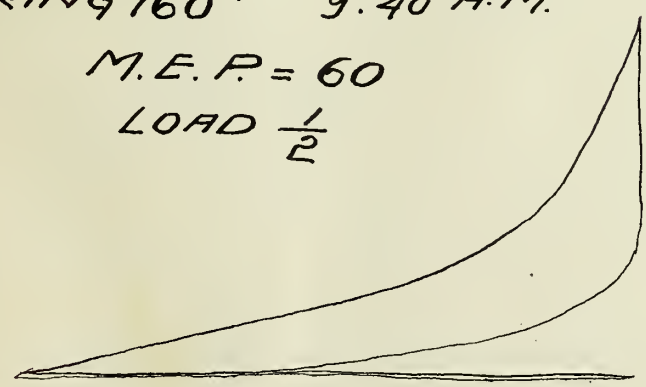
Assuming hard coal costs $6.oo per ton and soft coal for the steam plant $1.25 per ton,the gas power costs 1/2 cent and the steam power costs .63 cents. Even with coal at the above price, the producer plant still has a slight advantage. Other things being equal, such as the cost of installation and labor, the producer plant would seem the more desirable.

Curve No. 3. shows the relation between the thermal efficiencies of the plant and the brake loads.

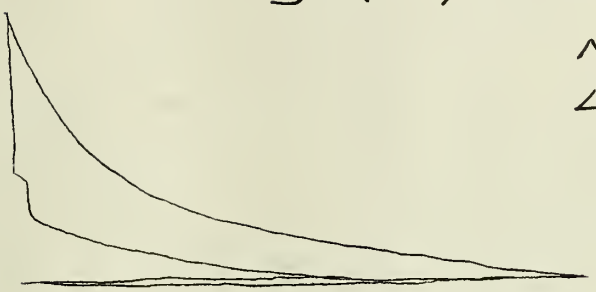
CARD Nº 11 3/26, '07.
SPRING 160# 1:15 P.M.
M.E.P. = 54.8
LOAD $\frac{1}{4}$



CARD Nº 2 3/29 '07.
SPRING 160# 9:40 A.M.
M.E.P. = 60
LOAD $\frac{1}{2}$



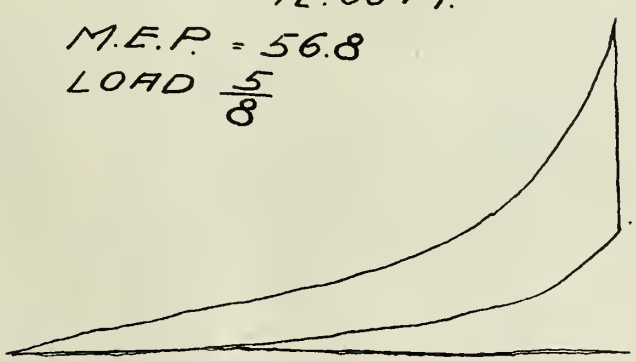
CARD Nº 22 4/11 '07
SPRING 120# 6:40 P.M.

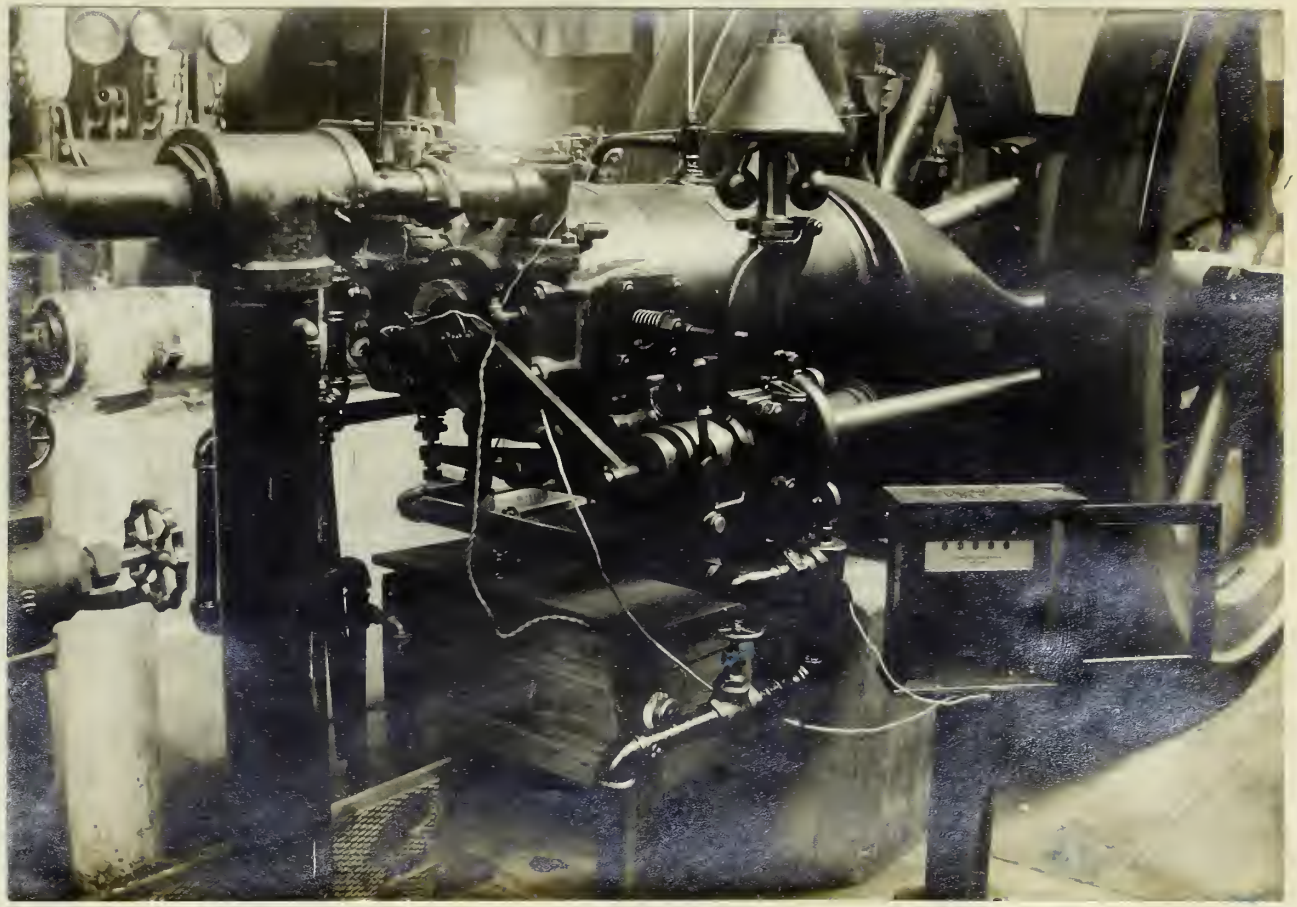


M.E.P. = 54
LOAD $\frac{3}{4}$

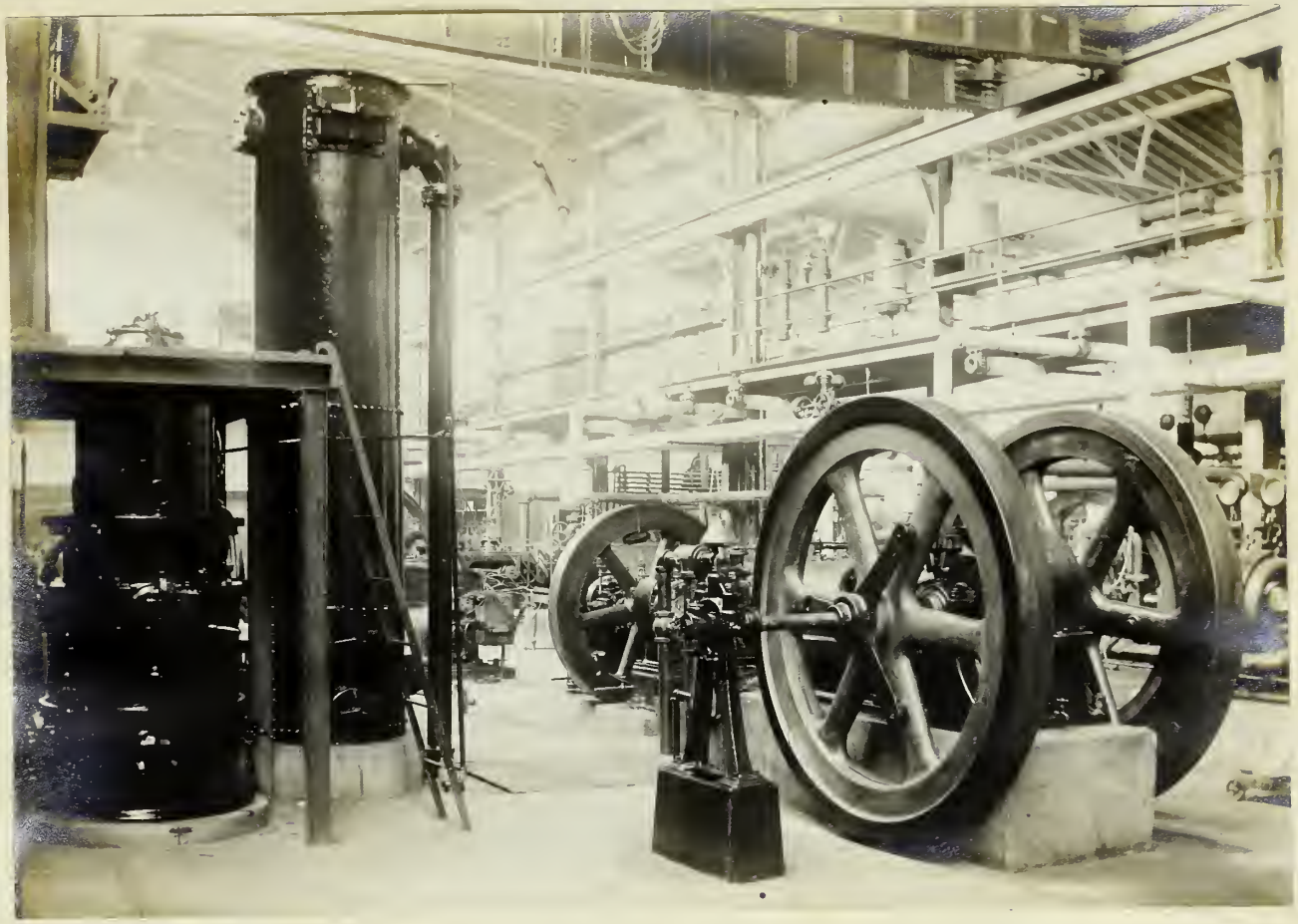
CARD Nº 9 4/9 '07.
SPRING 160# 12:00 M.

M.E.P. = 56.8
LOAD $\frac{5}{8}$

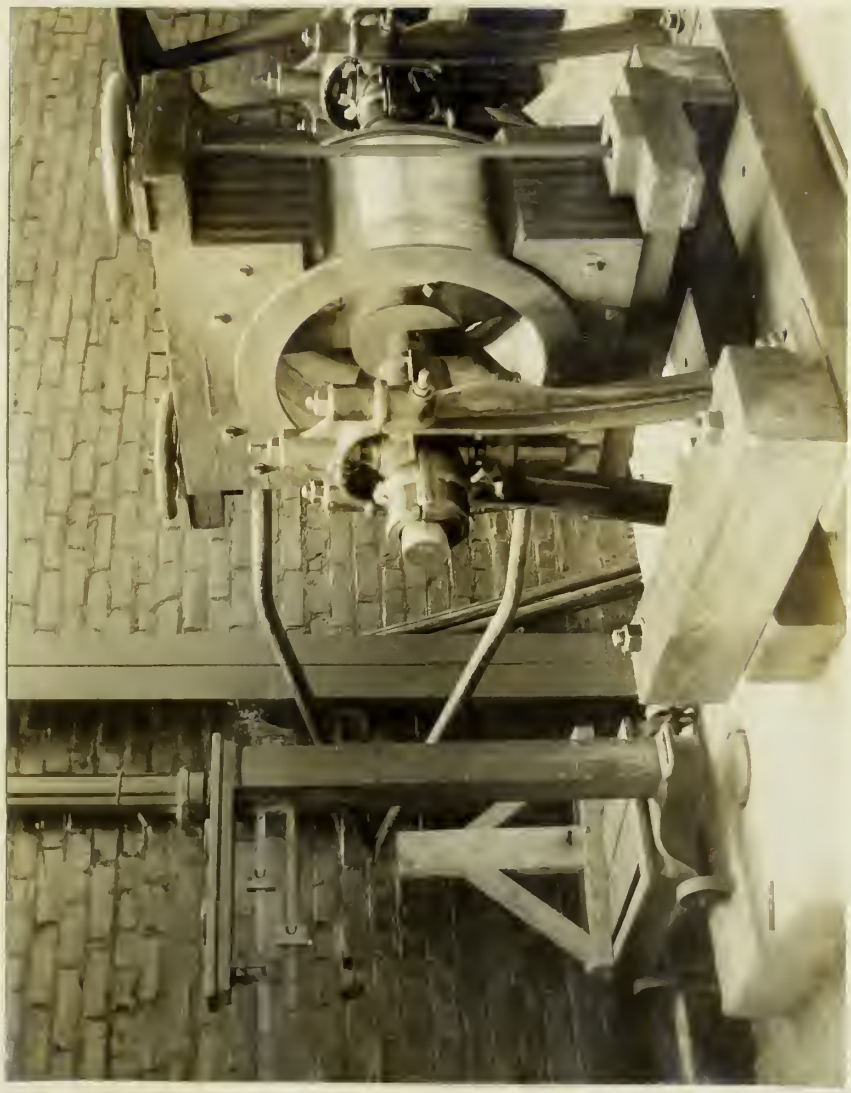




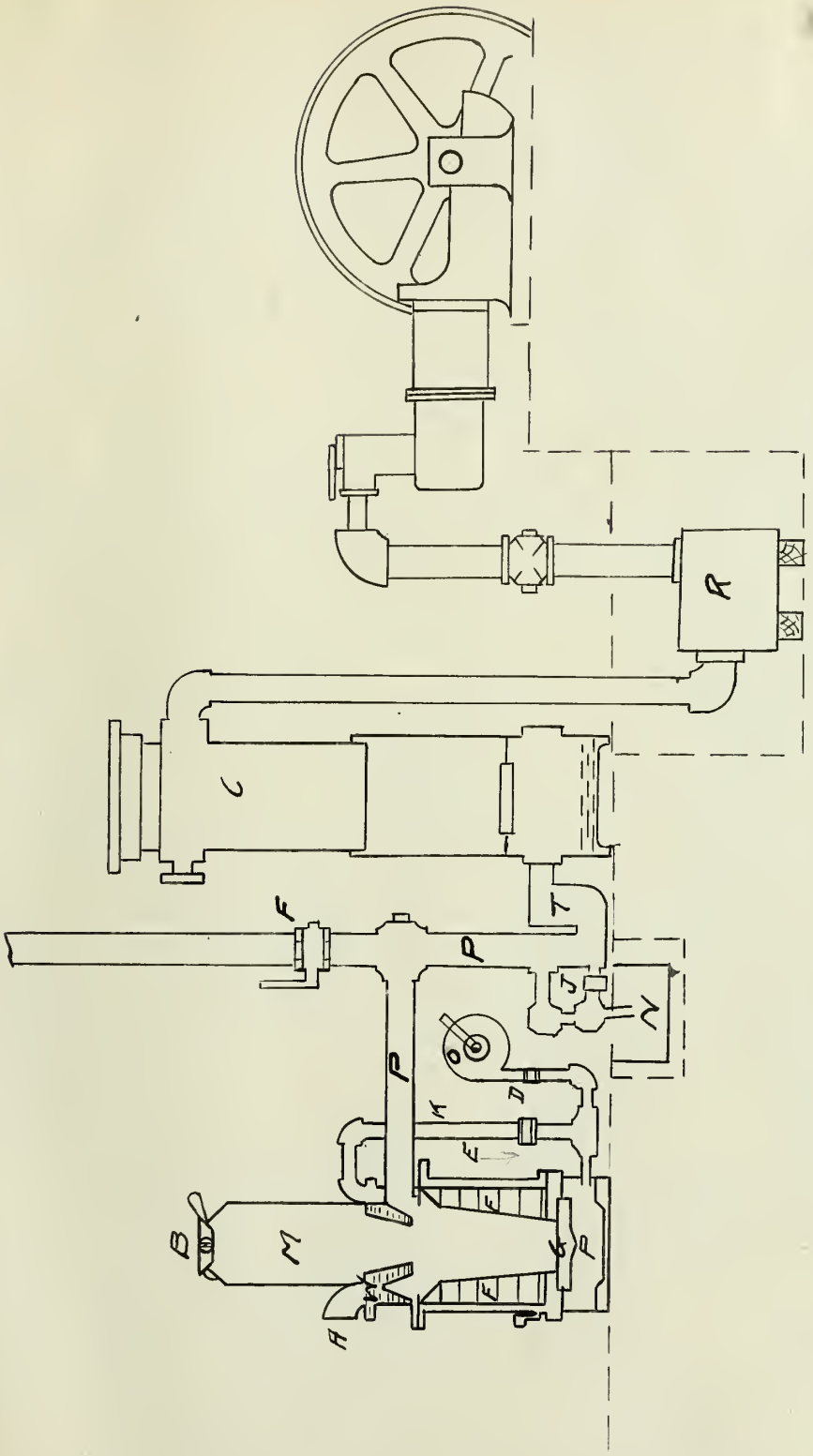
23 H.P. Otto Gas Engine.
No. 1.



Otto Suction Gas Producer and Engine.
No. 2.



Prony Brake.
No. 3



Diagramatic Sketch of Gas Producer & Engine No. 4.

CO

# FIRED	C
151	

TEST OF OTTO PRODUCER & ENGINE at 1/4 LOAD

Mar.26.1907.

TIME	TEMP. AT GAS AT PROD.	TEMP. AT GAS AT ENGINE	TEMP. AT GAS AT EXH.	TEMP. AT WATER IN	TEMP. AT WATER JACKET OUT	TEMP. AT WATER SCRUB. OUT	CU. FT. WATER JACKET	CU. FT. WATER PRODUCER	R.P.M.	EXPLOSIONS PER MIN.	POUNDS ON BRAKE	B.H.P.	I.H.P.	COAL # FIRED	COAL BTU CONTENT	# ASH	% MECH. EFF.	% THERM. EFF.	# COAL per B.H.P.H.	REMARKS
10:45	172	75	302	64	135	84			222	44	26.2	5.78	9.3							
11:00	205	76	310	61	105	102	4.24	4.76	221	58	26.2	5.76	12.3							
11:15	206	77	310	62	111	95	3:55	6.65	219	59	26.2	5.72	12.6							
11:30	203	78	308	61	94	85	6.5o	6.45	222	60	"	5.78	13.o							
11:45	213	78	308	61	100	79	4.63	6.55	221	61	"	5.76	12.2							
12:00	2:0	79	308	61	104	78	3.75	6.55	219	66	"	5.72	12.8							
12:15	227	80	312	61	106	75	4.14	7.08	217	67	"	5.68	12.5							
12:30	245	80	321	61	101	78	3.74	7.08	221	68	"	5.76	12.o							
12:45	264	82	317	61	99	78	4.14	8.04	218	63	"	5.68	13.3							
1.0	272	83	316	61	106	80	4.24	8.14	22o	62	"	5.74	13.1							
1:15	281	83	314	60	103	106	5.22	8.14	216	61	" "	5.63	12.9							
1:30	290	83	313	61	111	87	2.76	8.14	217	59	"	5.66	13.7							
1:45	301	83	313	61	118	85	3115	7.72	222	58	"	5.78	13.1							
2:00	297	83	315	61	114	100	3.35	7.61	221	59	"	5.76	14.3	151	13207	21#	45.5	6.05	3.02	
2:15	306	83	317	61	114	83	3.74	6.97	22o	59	"	5.74	14.3							
2:30	307	84	326	62	115	89	3.45	6.86	22o	56	"	5.74	12.6							
2:45	312	84	328	60	99	89	4.93	7.93	2.19	56	"	5.72	12.1							
3:00	318	84	328	60	97	91	5.73	6.98	221	55	"	5.76	11.7							
3:15	314	84	324	60	95	100	5.51	6.76	22o	53	"	5.74	13.6							
3:30	314	84	326	60	97	91	5.52	6.76	221	53	"	5.76	12.8							
3:45	318	84	324	60	97	89	5.32	6.45	221	49	"	5.76	11.oo							
4:00	303	84	328	60	97	86	5.41	6.66	219	48	"	5.72	11.3							
4:15	302	84	321	60	98	89	5.51	6.66	222	52	"	5.76	6.44							
4:30	286	83	321	60	96	87	5.42	6.66	221	54	"	5.76	12.7							
4:45	297	83	321	60	99	89	5.23	7.08	221	56	"	5.76	13.9							
5:00	301	84	324	60	110	86	3.74	7.61	---	56	"	----	----							
5:15	303	83	32o	61	111	85	3.55	7.84	221	55	"	5.76	----							
5:30	299	83	32o	61	109	80	3.74	7.71	22o	56	"	5.74	14.2							
5:45	307	83	32o	61	108	74	3.74	7.4o	221	55	"	5.76	12.9							
6:00	301	84	321	61	108	74	3.74	7.3o	222	6o	"	5.76	13.9							
6:15	312	85	328	61	11o	80	3.94	7.4o	219	59	"	5.72	13.5							
6:30	318	85	328	61	11o	78	4.04	7.2o	219	61	"	5.72	13.7							
6:45	326	86	328	61	108	80	3.64	7.4o	222	57	"	5.78	13.o							
7:00	369	86	326	62	108	78	4.oo	---	---	--	"	----	-----							
Averages	283	82	319	61	106	86			22o	57	26.2	5.75	12.64							
Totals							142.6	236.o5												

TI O A L

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9

9

1

1

1

1

228

4

4

4

4

5

5

Ave

Tot

TEST ON OTTO PRODUCT & ENGINE at 1/2 LOAD

Mar. [illegible], 1907

TIME	TEMPERATURE OF GAS AT EXH.	TEMPERATURE OF GAS AT ENGINE	TEMPERATURE OF GAS AT EXH.	TEMPERATURE OF WATER IN	TEMPERATURE OF WATER JACKET OUT	TEMPERATURE OF WATER SCRUB. OUT	CU. FT. WATER JACKET	CU. FT. WATER PRODUCER	R.P.M.	KILO'S. per Min.	POUNDS on BRAKE	B.H.P.	I.H.P.	COAL # FIRED	COAL B.T.U. CONTENT	# ASH	% MECH. EFF.	% THERM. EFF.	# COAL per B.H.P.H.	REMARKS
9:1[illegible]	316	73	324	64	182	76	----	----	222	82	52.4	11.58	16.00							
9:40	326	75	356	60	101	76	7.59	4.23	221	77	52.4	11.52	17.6							
9:[illegible]	330	76	372	60	106	74	5.32	4.76	222	79	52.4	11.58	16.7							
10:10	341	77	376	60	110	77	5.03	2.75	222	78	"	11.58	17.4							
10:25	345	79	381	60	110	78	4.83	3.80	220	86	"	11.48	19.5							
10:40	355	80	384	60	110	78	4.63	3.60	220	75	"	11.46	15.9							
10:55	358	82	389	60	114	78	4.63	3.49	220	82	"	11.46	16.3							
11:10	374	83	393	60	118	78	4.63	3.28	221	84	"	11.52	18.5							
11:25	381	83	397	60	117	79	5.02	3.49	221	78	"	11.48	18.7							
11:40	386	85	400	60	112	89	5.02	4.23	220	80	"	11.46	17.8							
11:55	386	85	397	60	107	89	5.42	4.13	220	82	"	11.46	18.4							
12:10	386	85	397	60	104	89	5.81	4.23	220	82	"	11.46	17.00							
12:25	387	88	395	60	106	89	5.71	4.23	217	82	"	11.58	19.3							
12:40	363	85	395	60	108	85	5.81	4.34	222	79	"	11.58	17.0							
12:55	374	85	397	60	110	83	5.42	4.13	224	76	"	11.68	17.1	228	13207	36.5	62.2	7.64	2.58	
1:10	389	85	394	60	112	82	4.93	3.91	220	80	"	11.46	16.7							
1:25	301	85	400	60	113	83	5.42	3.91	220	77	"	11.46	17.8							
1:40	279	85	404	60	116	82	5.03	3.70	219	77	"	11.41	18.4							
1:55	282	85	404	60	116	80	6.11	3.81	220	78	"	11.46	17.6							
2:10	296	85	404	60	116	80	4.24	3.71	219	77	"	11.41	16.3							
2:25	312	85	406	60	117	80	5.12	3.38	218	78	"	11.35	17.5							
2:40	313	85	409	60	118	80	6.11	3.38	220	--	"	11.46	#							# Indicator broken.
2:55	328	85	409	60	115	80	4.24	3.38	220	78	"	11.46	#							# Indicator broken.
3:10	341	87	413	60	115	80	5.42	3.38	220	81	"	11.46	16.2							
3:25	353	86	438	60	121	80	5.42	3.38	218	90	"	11.35	21.5							
3:40	368	87	413	60	117	39	5.42	3.38	218	95	"	11.35	22.4							
3:55	332	87	447	60	127	84	5.12	3.28	218	82	"	11.35	17.2							
4:10	328	87	451	60	111	83	5.91	2.64	218	107	"	11.35	24.2							
4:25	355	87	464	60	112	83	7.88	3.42	217	99	"	11.30	20.9							
4:40	324	88	450	60	116	60	7.19	3.28	179 #	93	"	9.32	19.6							# Clinker formation rapid
4:55	375	88	430	60	102	85	6.89	3.07	177 #	101	"	9.22	21.7							# " " "
5:10	314	88	442	60	107	84	7.39	3.28	219	83	"	11.41	15.0							# Vigorous poking of fire necessary.
5:25	318	88	438	60	105	81	6.89	3.07	218	--	"	11.35	15.6							
Averages	297	84	405	60	114	81			217	83	52.4	11.32	18.2							
Totals							179.00	116.12												

TI	C O A L	
	# FIRED	B T CONT
9:		
10:		
10:		
10:		
10:		
11:		
11:		
11:		
11:		
12:		
12:		
12:		
12:		
1:		
1:3	216	132
1:4		
2:0		
2:1		
2:3		
2:4		
3:0		
3:1		
3:3		
3:4		
4:0		
4:1		
4:3		
4:45		
5:00		
5:15		
5:30		
5:45		
6:00		
Average		
Totals		

TEST OF 60 H.P. PRODUCER & ENGINE at 5/8 LOAD

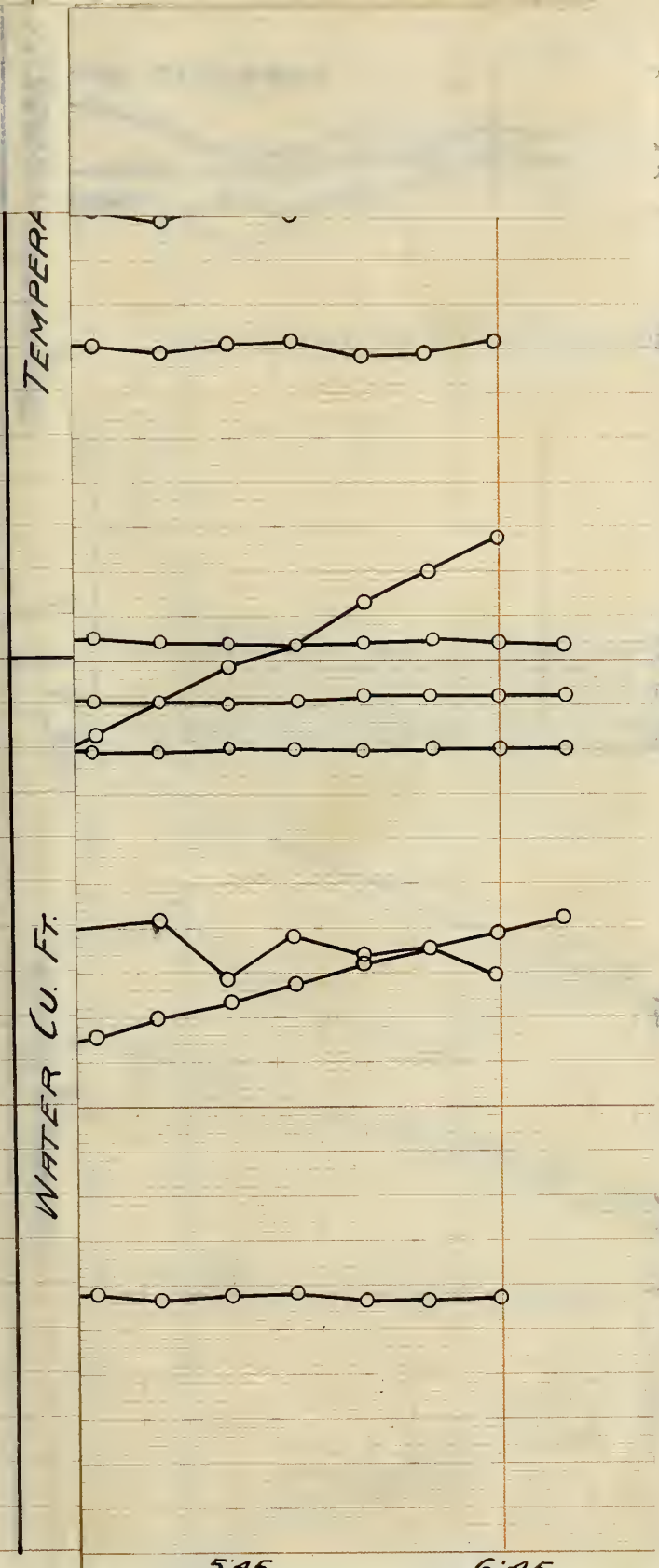
April, 9. 1907.

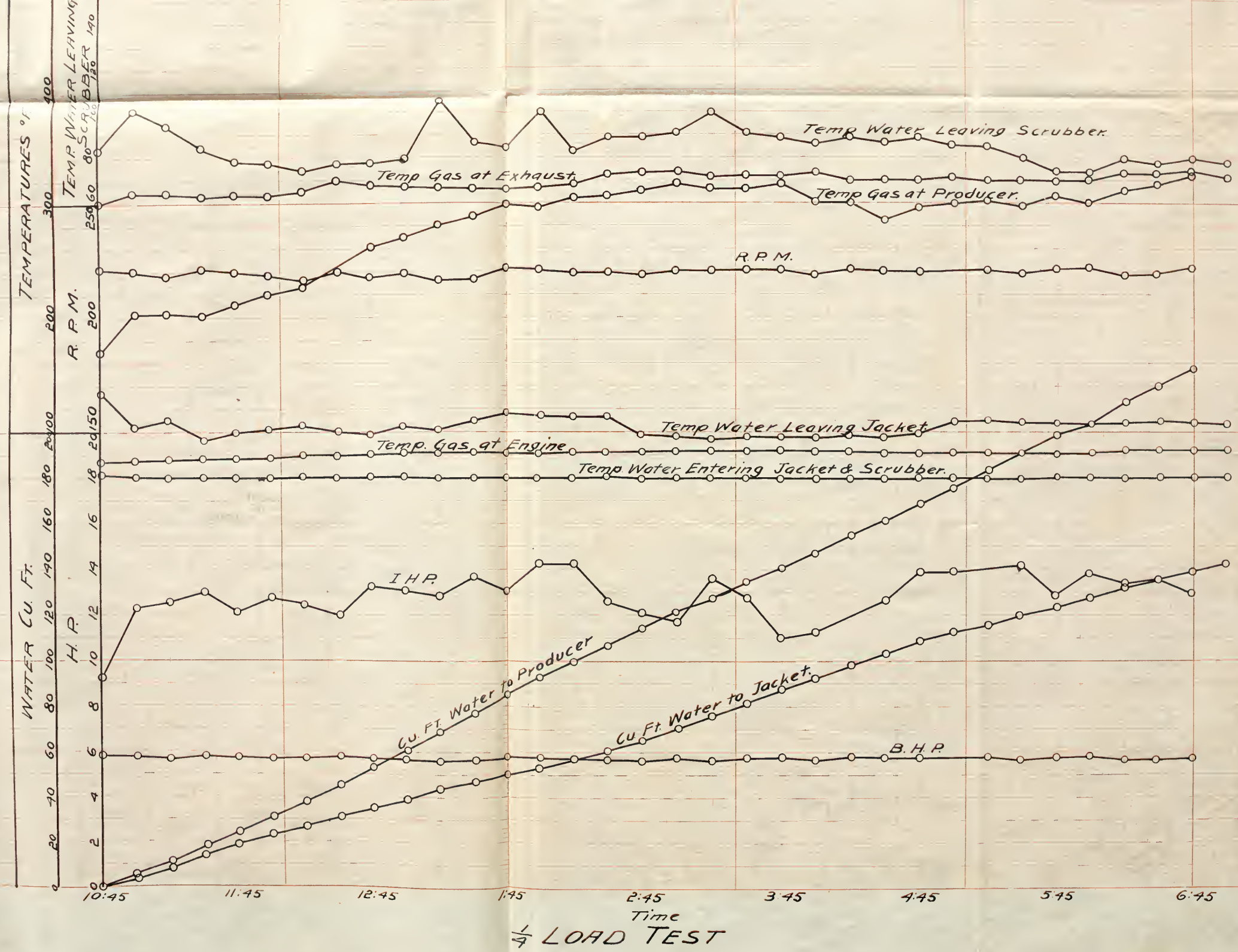
TIME	TEMP. GAS AT PRO.	TEMP. GAS AT ENGINE	TEMP. GAS AT EXH.	TEMPS OF WATER IN	TEMPS OF WATER JACKET OUT	TEMPS OF WATER SCRUB. OUT	CU. FT. WATER JACKET	CU. FT. WATER PRODUCER	R.P.M.	EXPLOS. per Min.	POUNDS on BRAKE	B.H.P.	I.H.P.	COAL # FIRED	COAL B.T.U. CONTENT	# ASH	% MECH. EFF.	% THERM. EFF.	POUNDS COAL per B.H.P.H.	REMARKS
9:45	168	72	417	60	113	68	---	----	207	104	65	13.38	----							
10:00	206	72	430	60	117	69	6.3	5.08	215	104	65	13.90	19.70							
10:15	228	73	432	59	104	69	6.45	4.86	222	99	"	14.35	19.9							
10:30	242	75	436	58	110	69	6.11	4.86	222	103	"	14.35	19.2							
10:45	243	75	444	59	113	68	6.11	4.76	222	104	"	14.35	20.2							
11:00	256	76	448	59	113	67	6.31	4.86	220	95	"	14.22	22.0							
11:15	264	78	450	60	115	70	6.31	5.40	222	95	"	14.35	19.2							
11:30	276	78	448	60	114	78	6.01	5.29	221	104	"	14.29	22.0							
11:45	286	79	455	58	115	72	6.01	5.29	220	104	"	14.22	21.0							
12:00	296	80	455	60	112	80	6.11	5.18	221	102	"	1429	22.2							
12:15	308	81	456	60	113	80	6.80	6.13	221	107	"	14.29	22.5 #							# Indicator broken.
12:30	324	82	459	60	114	81	4.82	3.92	220	99	"	14.22	--- #							# " "
12:45	345	83	455	62	113	81	6.60	4.86	218	95	"	14.10	--- #							# " "
1:00	350	85	455	62	111	86	6.31	4.76	220	103	"	14.22	---- #							# " "
1:15	346	86	455	60	116	84	6.31	4.55	220	103	"	14.22	---- #	216	13207	24	66.0	10.4	1.85	# Thermometer broken.
1:30	344	88	459	-- #	117	81	6.21	4.34	207	105	"	13.38	---- #							
1:45	348	88	456	59	115	81	6.01	4.12	217	106	"	14.20	21.70							
2:00	352	88	452	60	113	81	6.01	4.12	209	107	"	13.50	22.4							
2:15	347	87	455	60	118	81	5.81	3.92	214	93	"	13.82	20.7							
2:30	364	87	456	59	118	82	5.81	3.80	218	94	"	14.10	20.8							
2:45	358	87	456	60	119	79	5.71	4.76	219	93	"	14.15	20.0							
3:00	358	88	459	59	111	80	6.01	4.76	218	93	"	14.10	21.0							
3:15	374	86	455	58	106	80	6.80	4.97	217	97	"	14.02	21.7							
3:30	387	87	448	59	103	78	6.89	5.18	217	93	"	14.02	22.0							
3:45	407	88	448	59	108	80	6.99	4.97	218	96	"	14.15	21.7							
4:00	411	86	450	59	104	82	6.70	4.87	220	98	"	14.22	20.2							
4:15	410	87	450	59	112	81	5.91	4.55	222	99	"	14.35	23.4							
4:30	419	87	459	59	115	82	5.81	4.55	221	98	"	14.29	22.6							
4:45	414	87	459	59	119	82	5.71	4.33	220	98	"	14.22	22.6							
5:00	415	87	463	59	118	83	5.71	4.24	221	98	"	14.29	22.7							
5:15	403	88	463	60	119	82	5.71	4.33	220	95	"	14.22	21.1							
5:30	399	88	464	60	118	83	5.71	4.12	220	97	"	14.22	22.0							
5:45	407	88	463	60	118	83	5.62	4.12	220	97	"	14.22	22.5							
6:00	419	88	464	60	118	83	5.91	4.12	219	--	"	14.15	23.0							
Averages	338	83	452	60	114	78			218	98	65	14.12	21.4							
Totals							204.4	153.9												

C O A
FIRED
235.

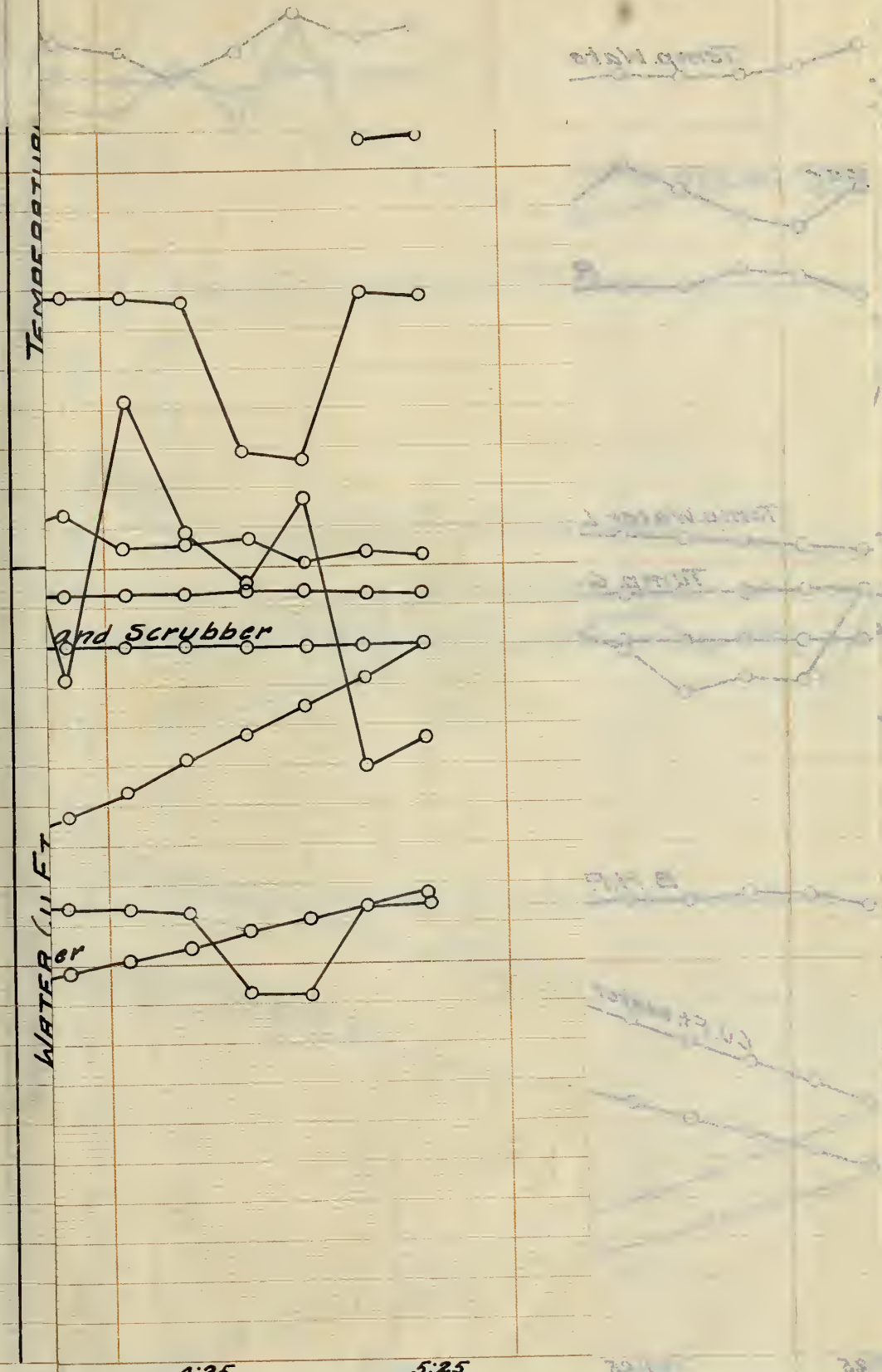
TEST OF OTTO PRODUCER & ENGINE at 3/4 LOAD.
April 11, 1907.

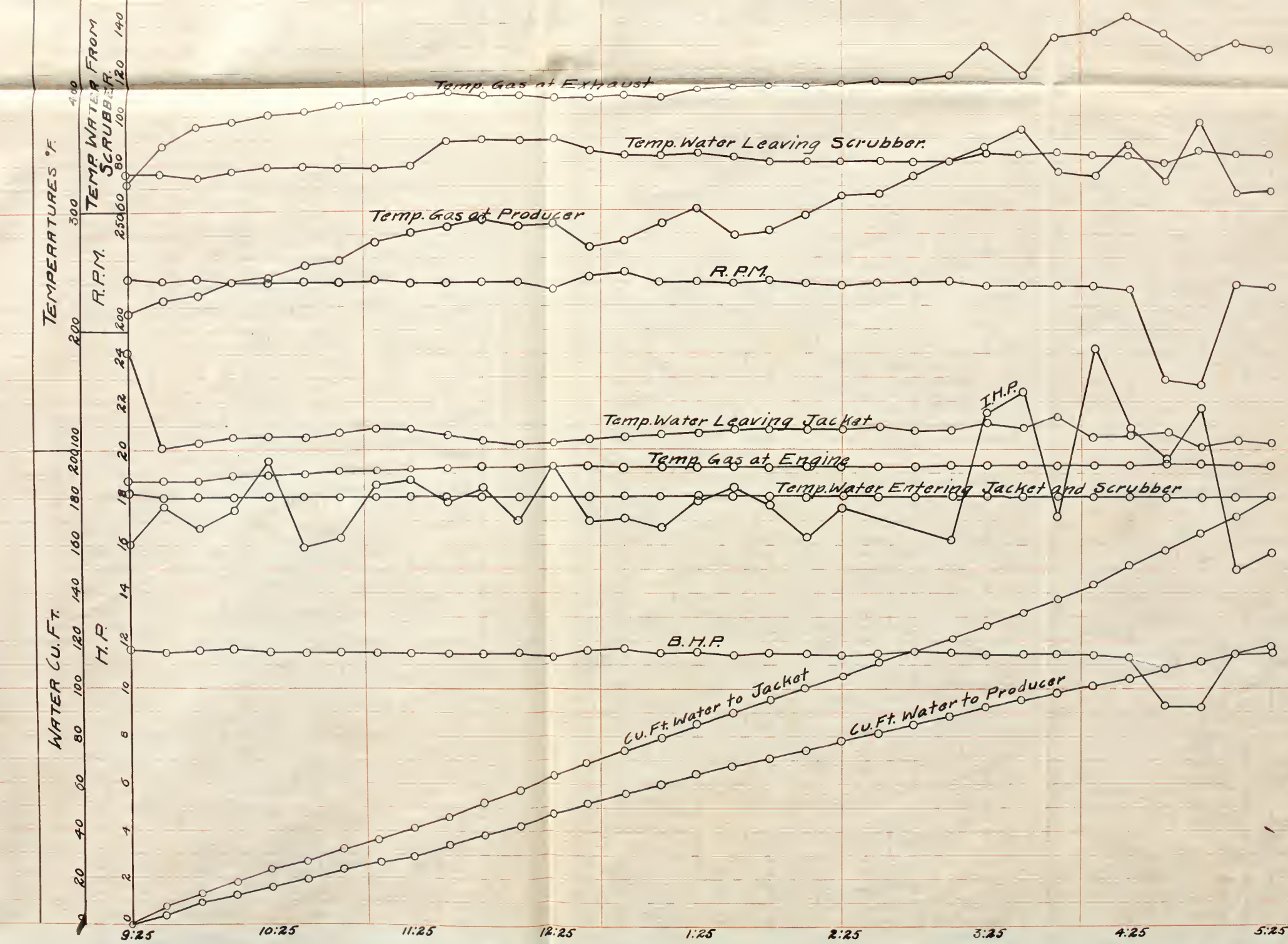
TIME	TEMPERATURE DEGREES F. GAS LEAV. PRO.	GAS AT ENGINE	GAS AT EXH.	WATER IN	WATER JACKET OUT	WATER SCRUB. OUT	LBS. WT. WATER JACKET	LBS. WT. WATER PRODUCER	R.P.M.	EXPLO'S per MIN.	POUNDS ON BRAKE	B.H.P.	I.H.P.	COAL # FIRED	COAL B.T.U. CONTENT	# ASH	% MECH. EFF.	% THERM. EFF.	# COAL per B.H.P. H.	REMARKS
1:25	282	77	356	59	106	70	----	----		105	75.00	16.02	23.7							
1:40	292	78	396	60	126	68	4.73	10.6	218	105	"	16.26	23.8							
1:55	259	80	402	60	134	71	4.54	7.5	218	105	"	16.26	24.2							
2:10	261	84	413	61	140	74	4.43	4.86	215	107	76.00	16.28	25.2							
2:25	268	84	414	58	90	76	10.82	4.97	218	107	"	16.50	25.1							
2:40	276	84	411	59	111	74	5.90	4.86	207	92	"	15.67	21.5							
2:55	280	81	401	60	115	76	6.60	5.40	199	104	"	15.06	22.8							
3:10	286	81	410	60	118	76	6.10	5.08	202	106	"	15.28	22.6							
3:25	291	82	431	60	120	76	5.91	4.96	216	107	"	16.34	21.3							
3:40	300	82	441	60	115	77	6.40	4.76	215	94	"	16.28	20.8							
3:55	341	83	448	60	118	76	6.50	4.86	216	108	"	16.34	22.0							
4:10	343	82	450	60	115	75	6.50	5.29	214	117	"	16.20	23.4							
4:25	343	83	444	65	115	75	6.70	5.40	210	92	"	15.88	24.8							
4:40	343	86	442	60	111	76	6.70	5.40	219	96	"	16.57	21.2							
4:55	361	87	442	62	110	75	6.40	5.19	219	92	"	16.57	21.6							
5:10	361	88	444	60	110	78	6.70	5.40	220	92	81.00	17.72	21.9							
5:25	361	89	443	60	110	76	6.70	5.50	219	107	85.00	18.53	22.5	235.	13207	28	74.5	7.4	2.61	
5:44	368	90	459	60	110	76	7.30	5.92	220	--- #	"	18.61	----							
5:55	353	90	459	59	112	76	6.03	4.02	219	--- #	"	18.53	----							# Rapid formation of clinker
6:10	349	91	443	62	112	75	4.90	7.50	194	88	"	16.42	18.5							# " " " "
6:25	344	93	363	62	104	73	7.90	6.45	---	89	"	----	18.9							
6:40	364	91	411	63	108	73	7.90	9.00	167 #	89	"	14.12	18.7							# Explo. Counter out of order.
6:55	351	86	380	62	98	64	6.60	9.20	182 #	89	"	15.40	18.7							# " " " " "
Averages	319	85	422	61	113	74			210	99	79.00	16.40	22.06							
Totals							144.53	132.13												


TEMPERA
WATER CU. FT.
5:45
6:45

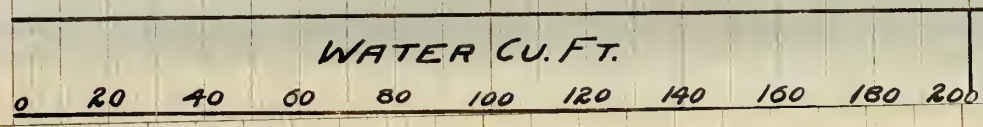


$\frac{1}{4}$ LOAD TEST

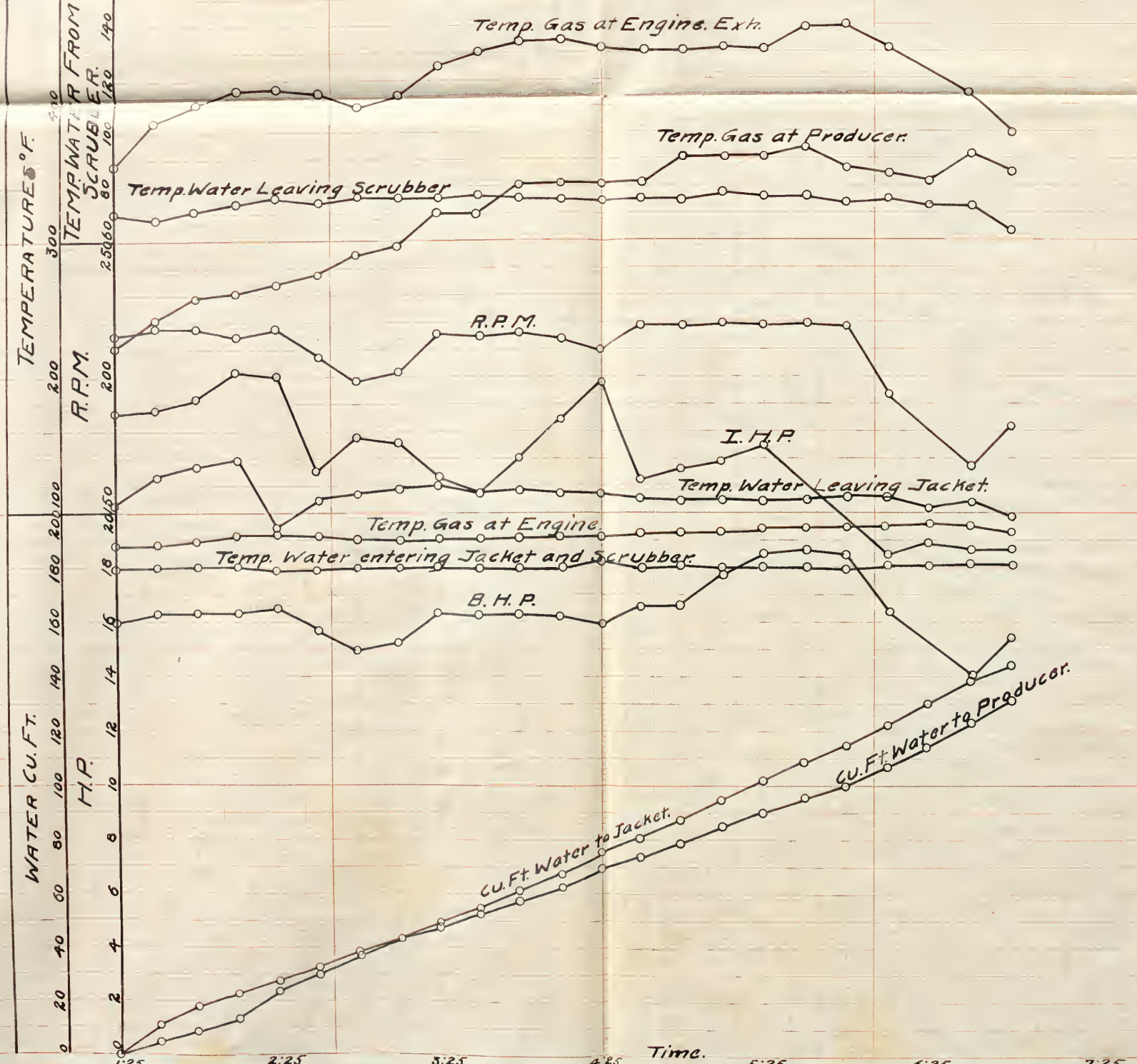

Temperature
and Scrubber
Water (11 Ft
er
4:25
5:25


Temp. Gas at Exhaust
Temp. Water Leaving Scrubber.
Temp. Gas at Producer
R.P.M.
I.H.P.
Temp. Water Leaving Jacket
Temp. Gas at Engine
Temp. Water Entering Jacket and Scrubber
B.H.P.
Cu. Ft. Water to Jacket
Cu. Ft. Water to Producer
TEMPERATURES °F.
TEMP. WATER FROM SCRUBBER
R.P.M.
H.P.
WATER CU. FT.
9:25
10:25
11:25
12:25
1:25
2:25
3:25
4:25
5:25

½ LOAD TEST

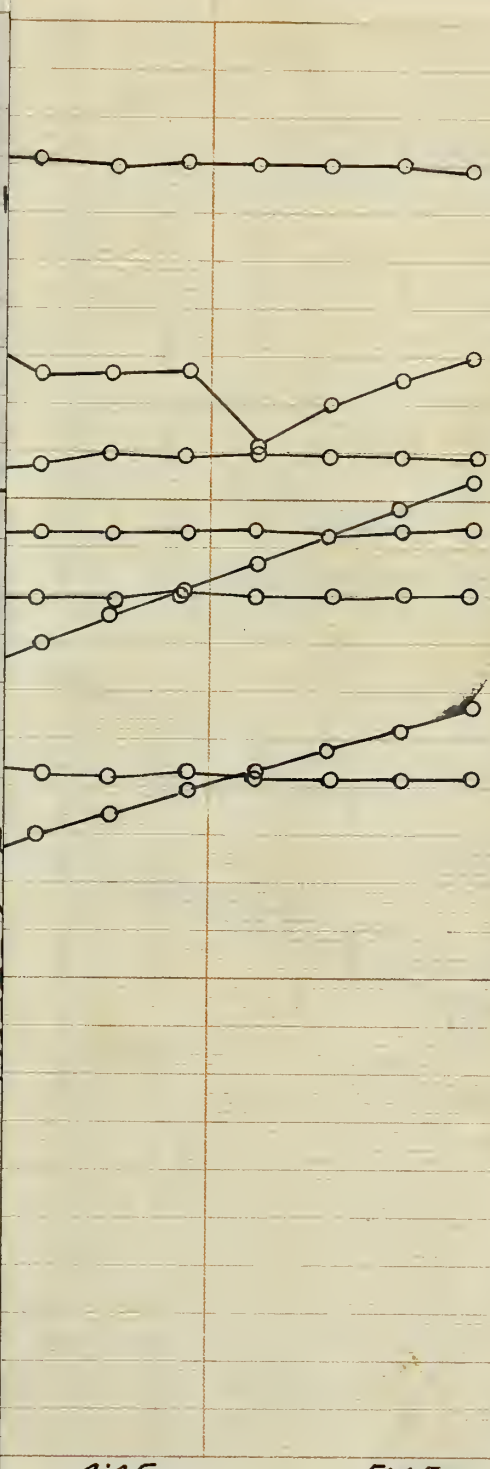


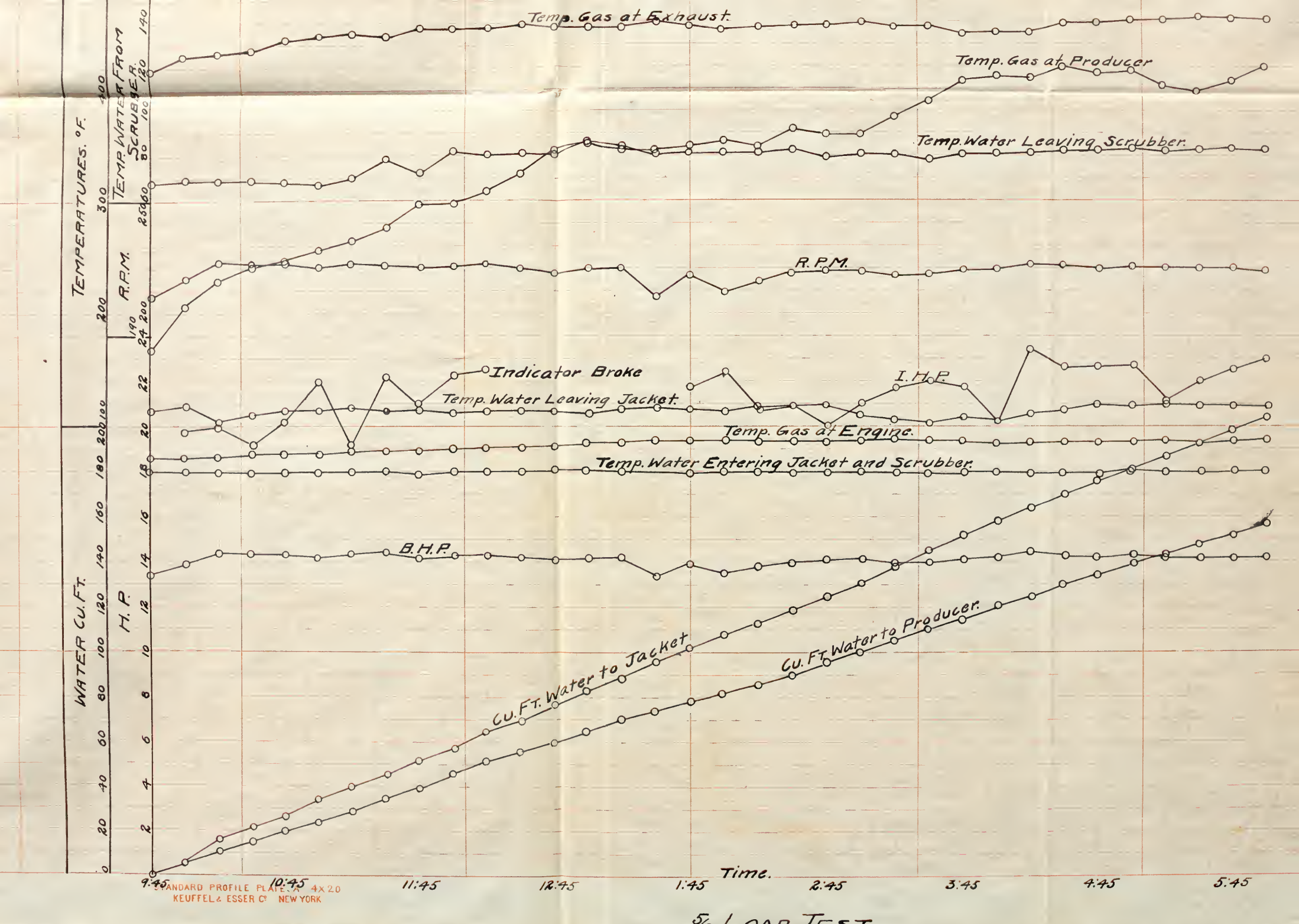
STANDARD PROFILE
KEUFFEL & ESSE



STANDARD PROFILE PLATE 4X20
KEUFFEL & ESSER CO NEW YORK

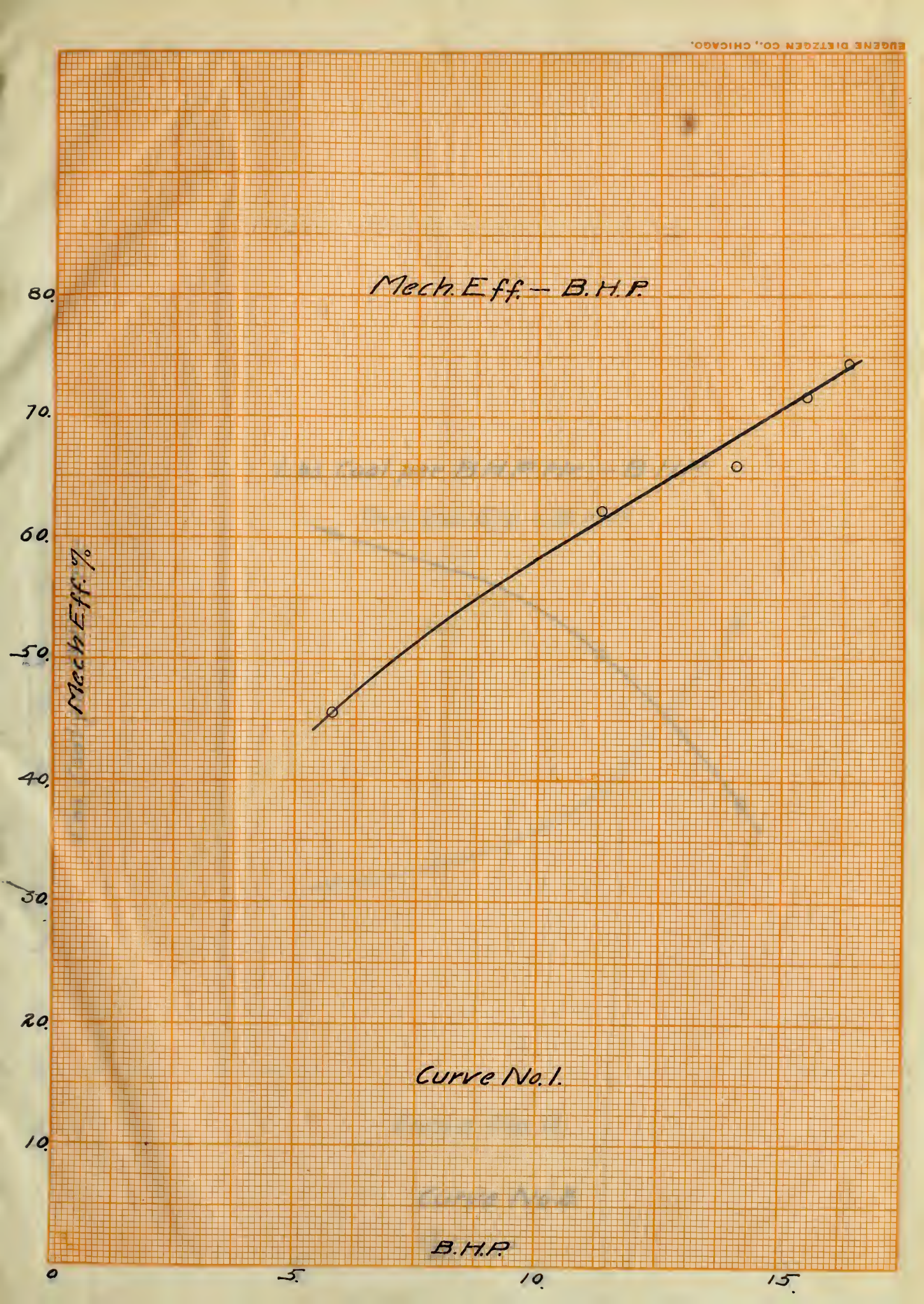
3/4 Load Test.


4:45
5:45


Temp. Gas at Exhaust.
Temp. Gas at Producer
Temp. Water Leaving Scrubber.
R.P.M.
Indicator Broke
I.H.P.
Temp. Water Leaving Jacket.
Temp. Gas at Engine.
Temp. Water Entering Jacket and Scrubber.
B.H.P.
Cu. Ft. Water to Jacket
Cu. Ft. Water to Producer.
TEMPERATURES. °F.
TEMP. WATER FROM SCRUBBER.
R.P.M.
H.P.
WATER CU. FT.
Time.
9:45
10:45
11:45
12:45
1:45
2:45
3:45
4:45
5:45
STANDARD PROFILE PLATE A 4X20
KEUFFEL & ESSER Co NEW YORK

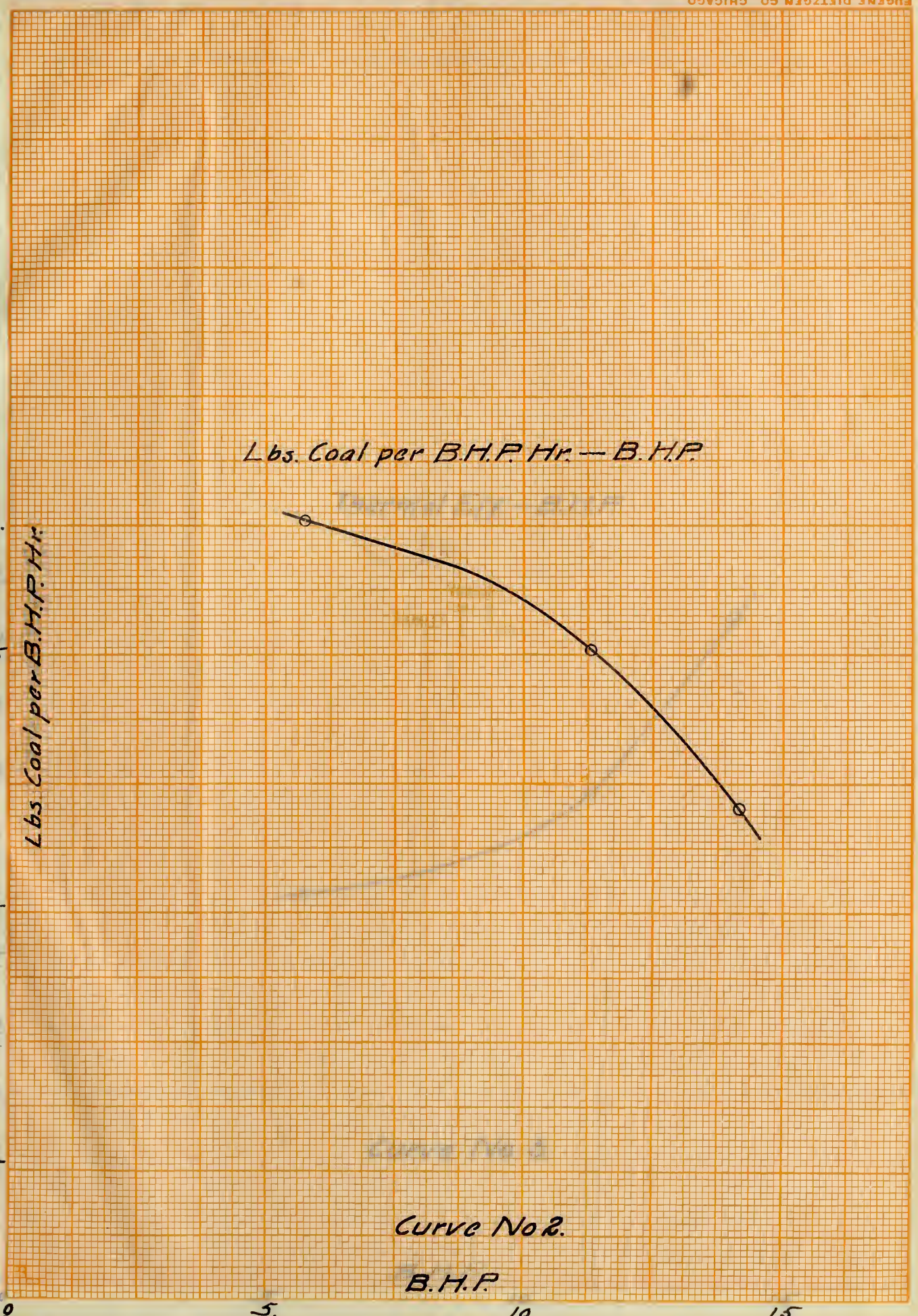
5/8 LOAD TEST.

EUGENE DIETZGEN CO., CHICAGO.



Curve No. 1.

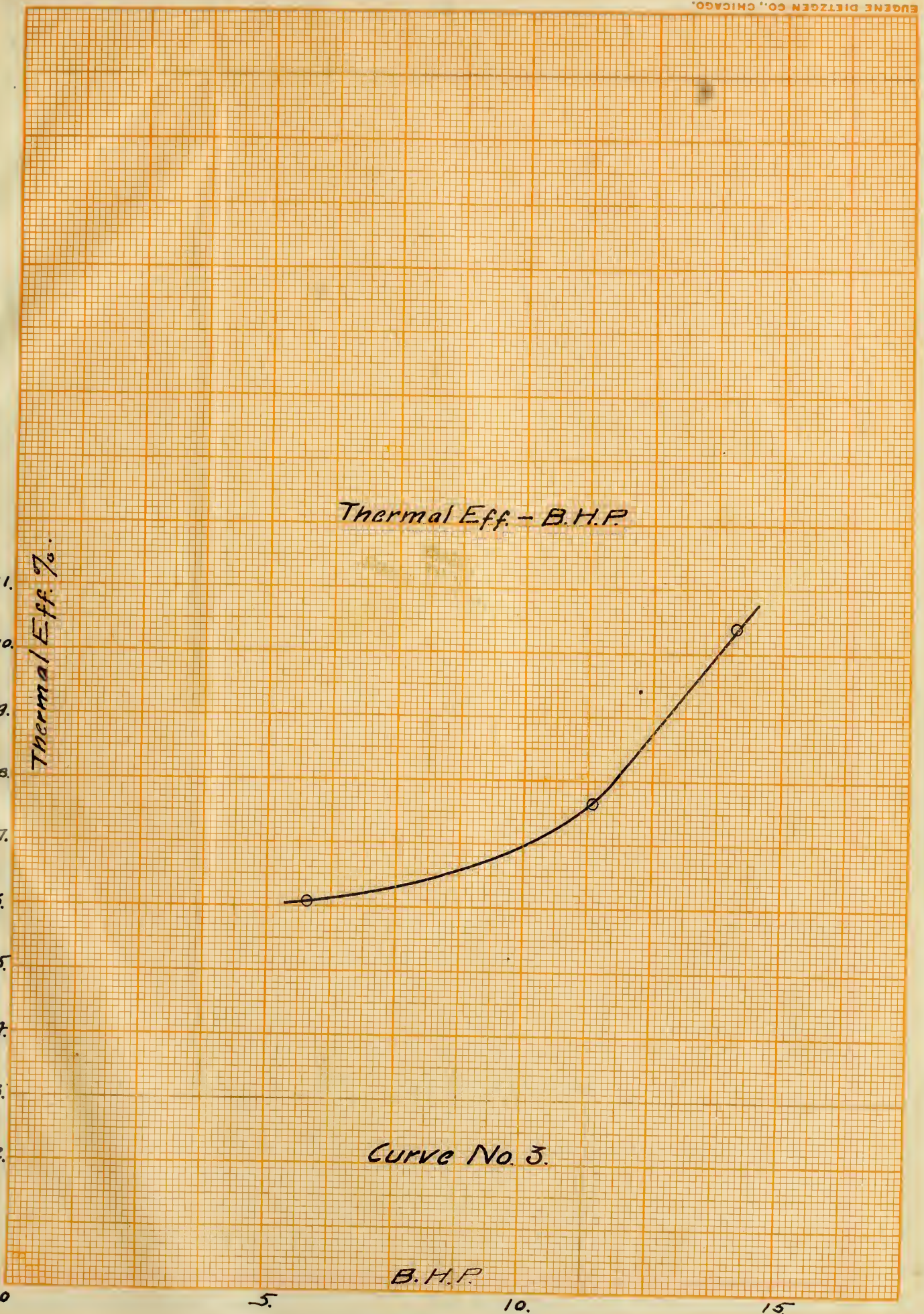
EUGENE DIETZGEN CO., CHICAGO.



Curve No 2.

Lbs Coal per B.H.P. Hr. — B.H.P.
3.
2.5
2
1.5
1
.5
0
5.
10.
15.
Curve No 8.
B.H.P.

EUGENE DIETZGEN CO., CHICAGO.



Curve No. 3.

UNIVERSITY OF ILLINOIS-URBANA
3 0112 079824758